Through-going muons analysis

neutrino.lbl.gov/∼snoman/currat/talks/

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Muon group workshop, Vancouver BC

- Update on muons generation in Snoman v.4_0286
- First attempt to reproduce 2001 analysis
- Perspectives

Muon code

Level of description of muon simulation in Snoman has fairly increased in 2 years (J. Formaggio):

- Bremsstrahlung, Moller scattering (knock-on electrons), decay vs muon capture, pair generation, `LEPTO` for DIS in photo-nuclear interactions, neutron production

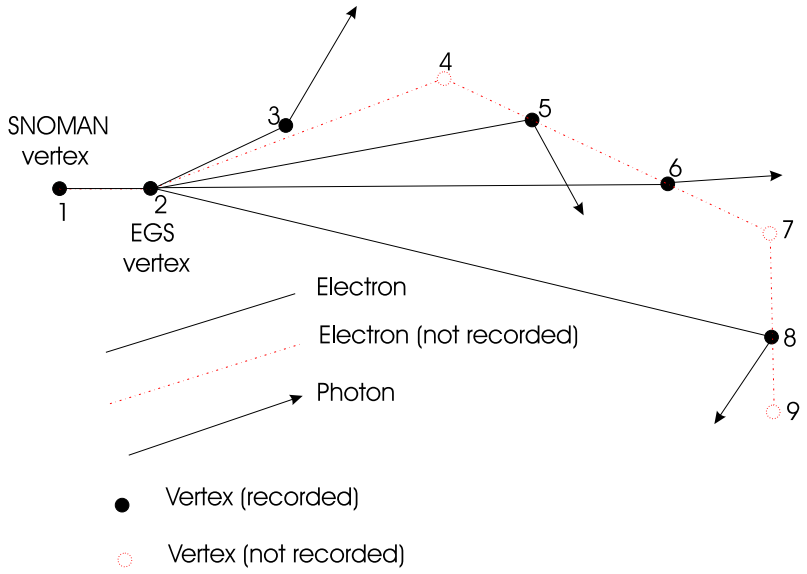
A couple of bugs have been fixed recently in the muons generation code (C.C.). They all eventually resulted in a "`Store full`" error for $E(\mu) > 500$ MeV up to v.4_0285

- v.4_0285 fixes the muon capture on ^{16}O seen in v.4_0282
- typo in the determination of outgoing μ direction in elastic scattering
- hadrons might never get recognized as at rest (tolerance around rest mass criterion) and would never stop
- no check on the energy lost in the last step before μ gets at rest ⇨ O(100 MeV – 1 GeV) of unphysical energy in the event
- initialization of the cross sections for μ interactions

Recommendations

Found stable running conditions for generating MC muons in Snoman (as of v.4_0286)... read "avoiding the data structure to fill up to the top in a fingersnap"

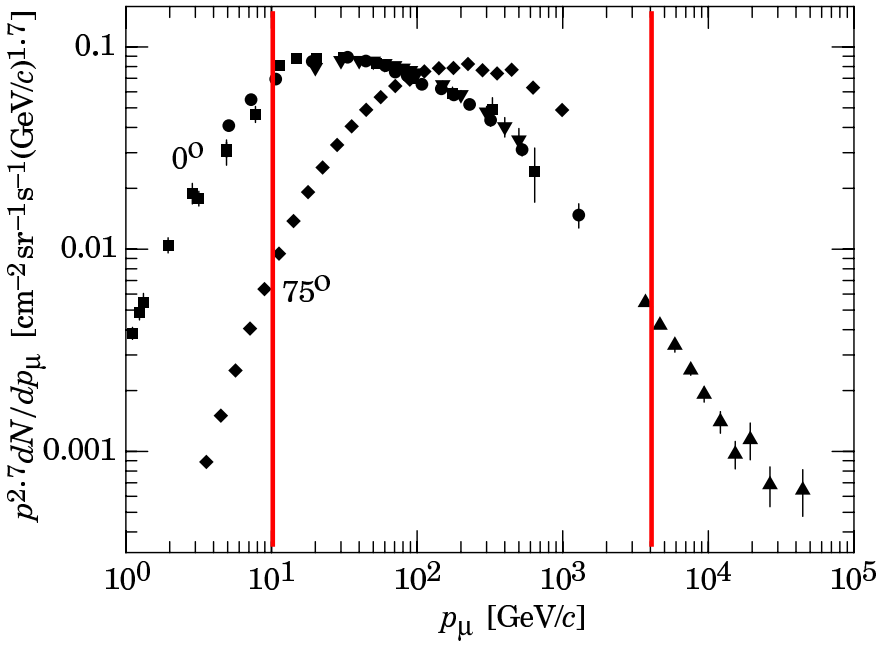
- Belly plates geometry is tricky and prompts crashes ➪ OK when disabled, `$disable_geom $bly_xxx`
- Average muon event induces generation of O(10^6) vertices of all kinds ➪ they must be dropped: `$killvx 7, $killvx_neutron 5` (NB: `$killvx 9` drops the initial MC track...)
- The abundant electrons generated along muon path yield showers simulated in details ➪ disable EGS4 data structure logging, `$egs4_ds $off`



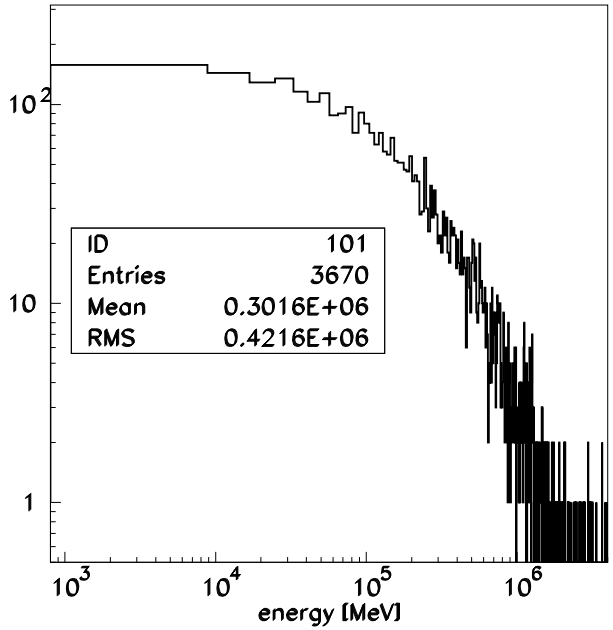
Cosmics

Now generation of muons over full range of cosmics energy spectrum is possible
⇨ up to several TeV!!

from Gaisser [PDG]



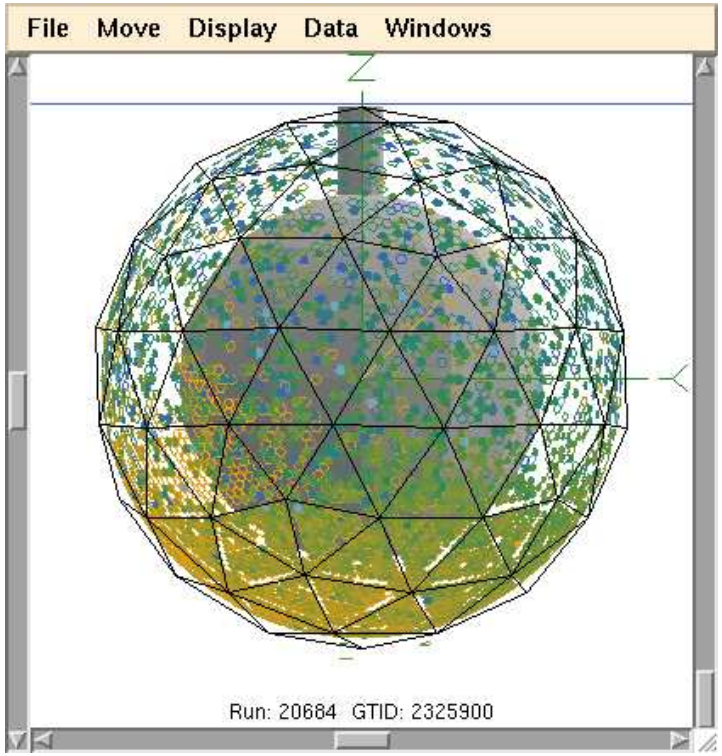
Snoman MC cosmics output

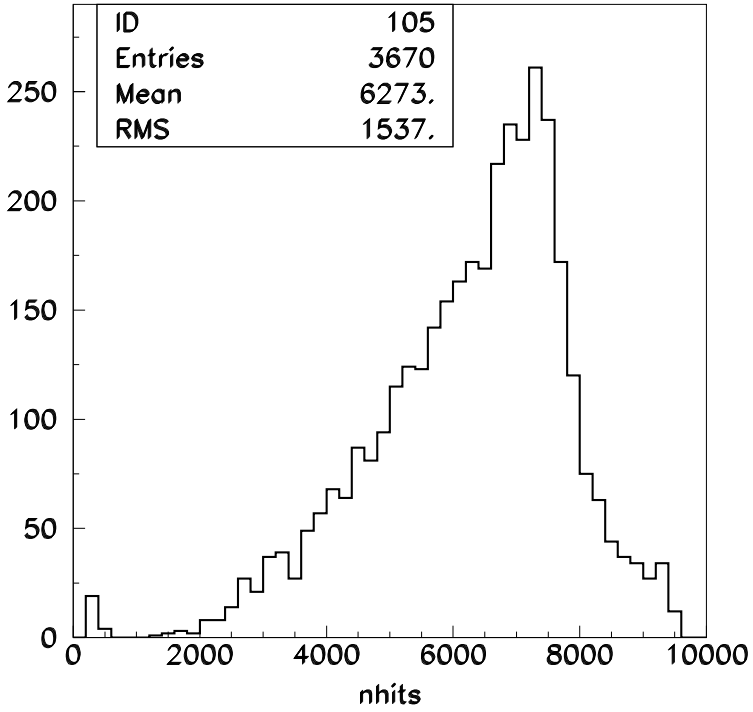


☞ Nice achievement to accomodate TeV-muons and/down-to thermal neutrons in the same code, about 14 orders of magnitude difference...!!

Production

Sample of 4000 events: 35 fatal geometry errors, 32 store full errors ⇨ sub-percent level! (event selection bias free?)





- Setup machinery on Berkeley's NERSC facilities (256 nodes) for (massive) generation. Count 8h/100 events. Output is light, essentially ntuples.
- "Overnight" philosophy quite achievable, idem for data (see further)

The muon fitter

Presently used "as is", developed by N. Tagg (2001). 5 independent pars that specify a μ track: time t_f it left PSUP, exit point on PSUP (θ, ϕ), direction (η, ψ)

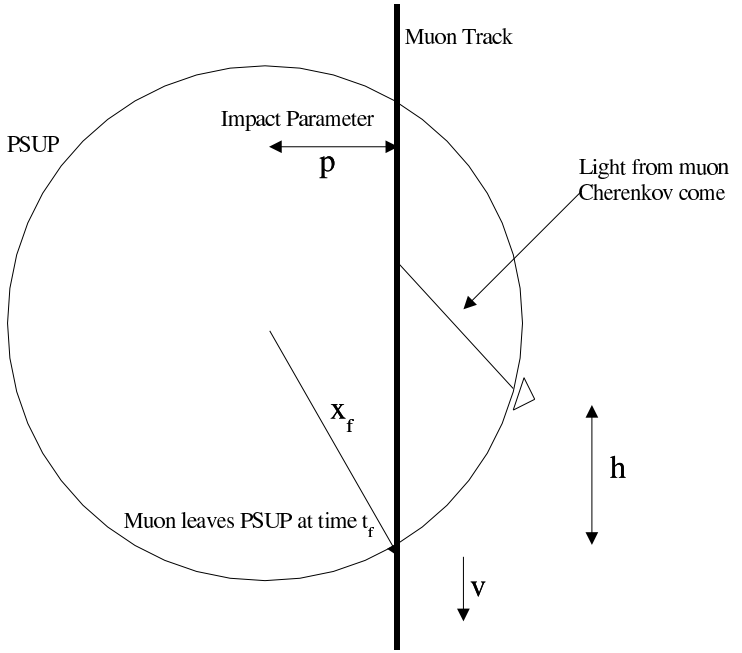
☞ (1) cull down list of "good" tubes to ∼1000 / (2) educated guess of exit wound / (3) use of PMTs timing to find direction

- high charge ∼ accurate time, cut on low-charge tubes on an evt/evt basis $q_i > 1.2 \times \langle q \rangle_{evt}$
- initial pars: guess for exit vertex by charge-weighted cluster, time given by last (uncut) tube to fire
- search for direction and exit position on a grid ⇨ minimization for t_f

$$\chi^2 = \sum_i \frac{(t_i - t_i^{fit})^2}{(\sigma_t^{PMT})^2}$$

with $\sigma_t^{PMT} = 1.6$ ns and $t_i^{fit} = t_f + \frac{1}{c} d(x_i^{PMT}, \theta_C)$ assuming direct Cherenkov light. Late tubes thrown out, $|t - t^{fit}| < 10$ ns

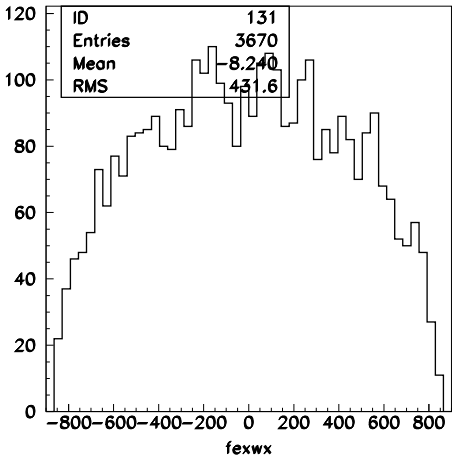
- for best χ^2 scenario, full minimization $(\theta, \phi, \eta, \psi, t_f)$, throw out tube with worst χ^2 contribution, iterate

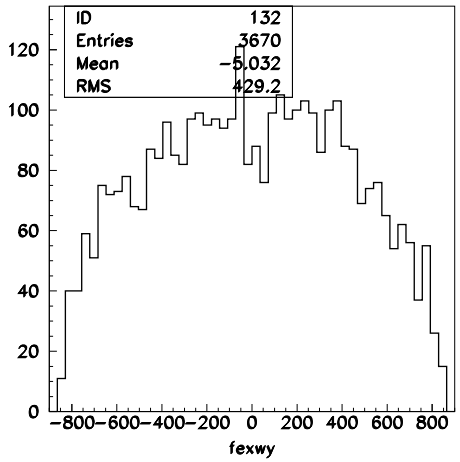


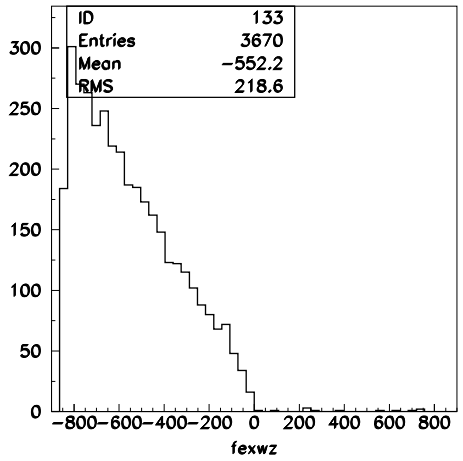
Fitter perfs 1/2

Fitted exit wound location after full minimization (FTM core)

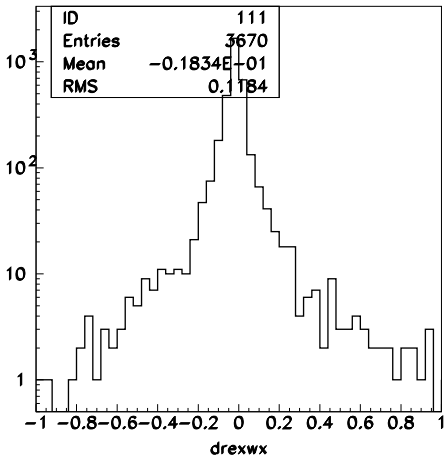
Exit wound: fitted position in [cm]

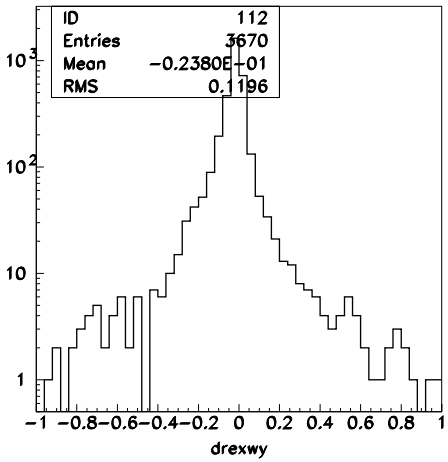


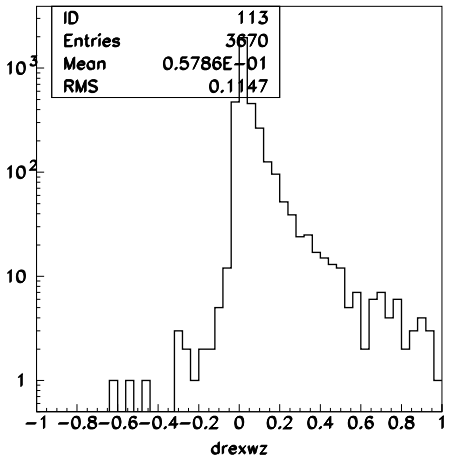




Exit wound: (MC-fit)/MC



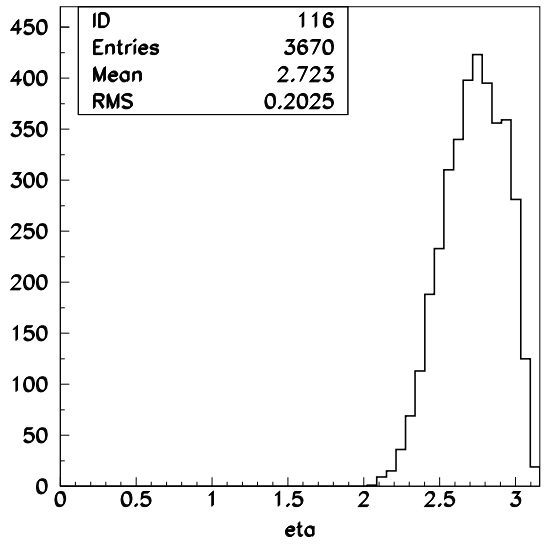


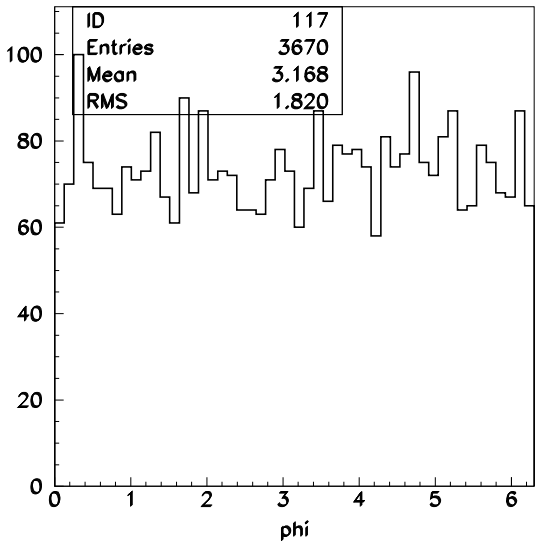


Fitter perfs 2/2

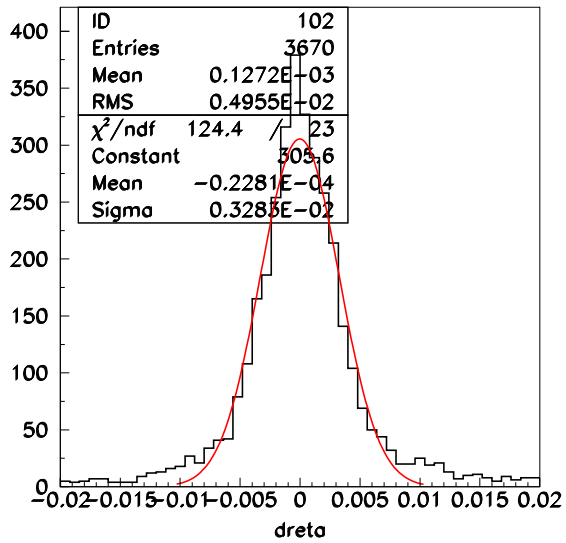
Fitted direction after full minimization (FTM core)

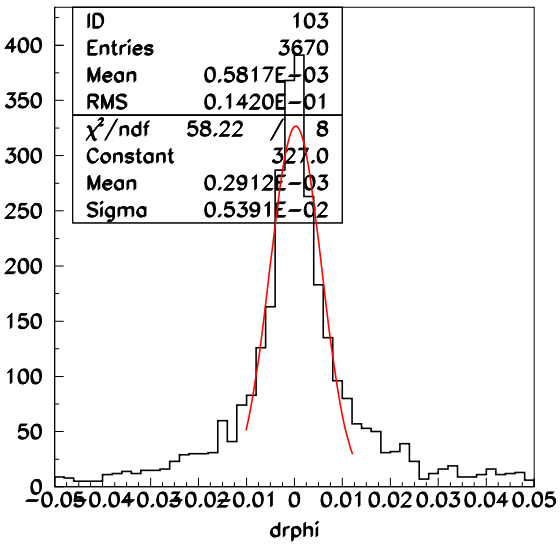
Muon direction (η, ψ)





Muon direction: (MC-fit)/MC

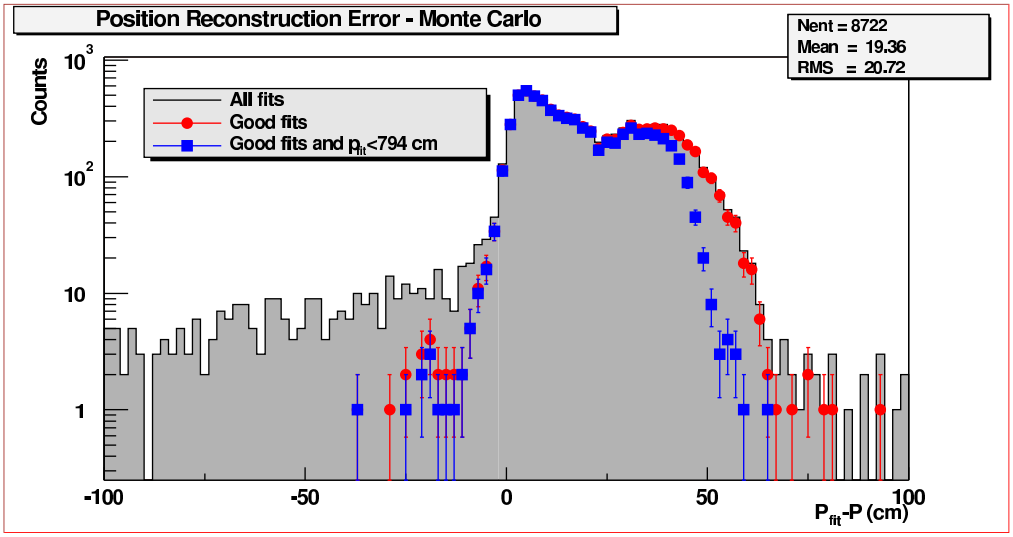




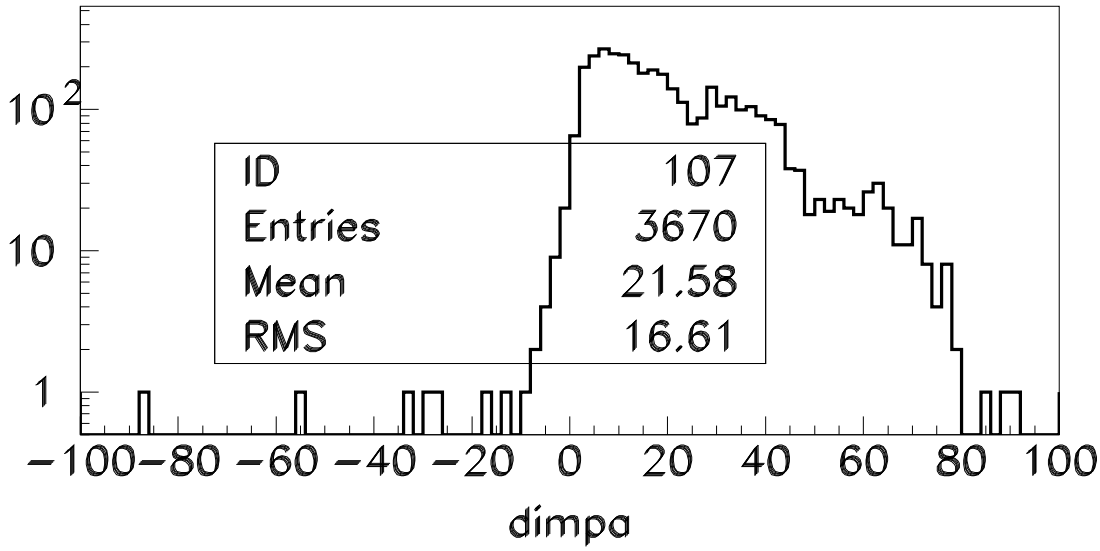
☞ Error on direction seems to usually be less than 1° (good!)

Impact parameter

From N. Tagg's thesis (2001). "Good hits" cut removes poor fits (e.g. skimming muons at large impact parameter)



Current MC with default settings for cosmics $p - p_{fit}$ [cm]



☞ The μ-fitter appears to be (still) working and presumably with the same performance. Reassessment of figures of merit to be carried out though.

Data selection

First pass analysis to assess the fitter performance and cuts validity with salt data, also data blindness test.
Reminder: original analysis (N. Tagg) used 149 days of D2O data, runs 10000–12168 (Nov'99–Jun'00)
Largest problem in μ analysis is rejection of instrumental backgrounds

- flashers
- electronic pickup
- neck light ("manipulight")
- high-voltage breakdown
- re-triggers
- tubes off, dead regions ⇨ anisotropies
- orphan events

⇨ detector operation working in 'neutrino' mode as opposed to 'supernova' mode.

Cuts used in the 2001 analysis:

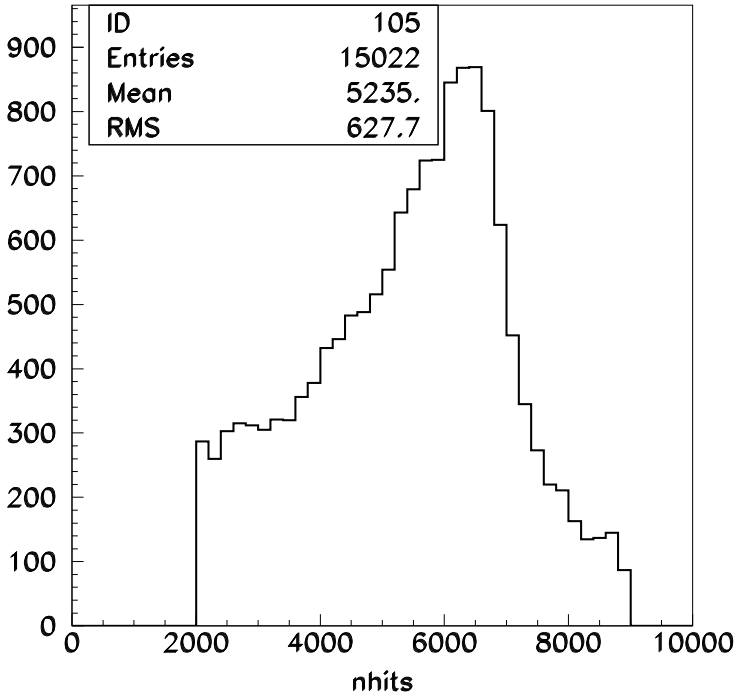
- $150 < N_{hit} < 10000$, basic energy cut
- retrigger cut
- junk cut
- Q/NHIT
- neck tube cut (dead time window)
- t_{RMS}

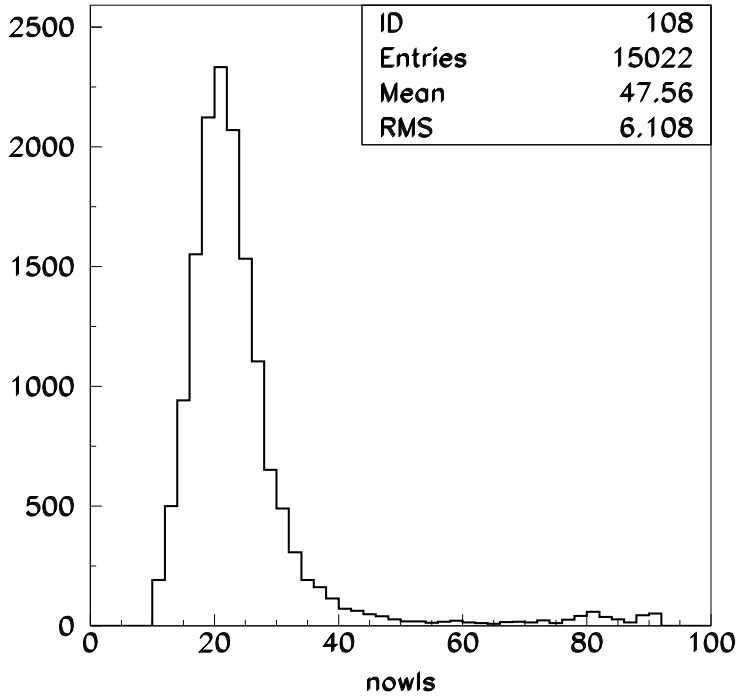
⇨ reduction of raw data by 10^4

☞ Results shown here use salt phase set I data, 254 days, runs 20684–26997
Total data amounts 300+254+151=705 days ⇨ factor 4.7 times more statistics than original analysis
FYI: Salt set I takes overnight processing of 15 jobs (all ZDABs and DQXXs files on disk, no fitted event info saved)

Further selection

Applying prescribed cuts through the DAMN bits. Additional clean-up performed by cutting on N_{hit} (rough!) and using the OWL tubes ($N_{OWLS} > 10$)

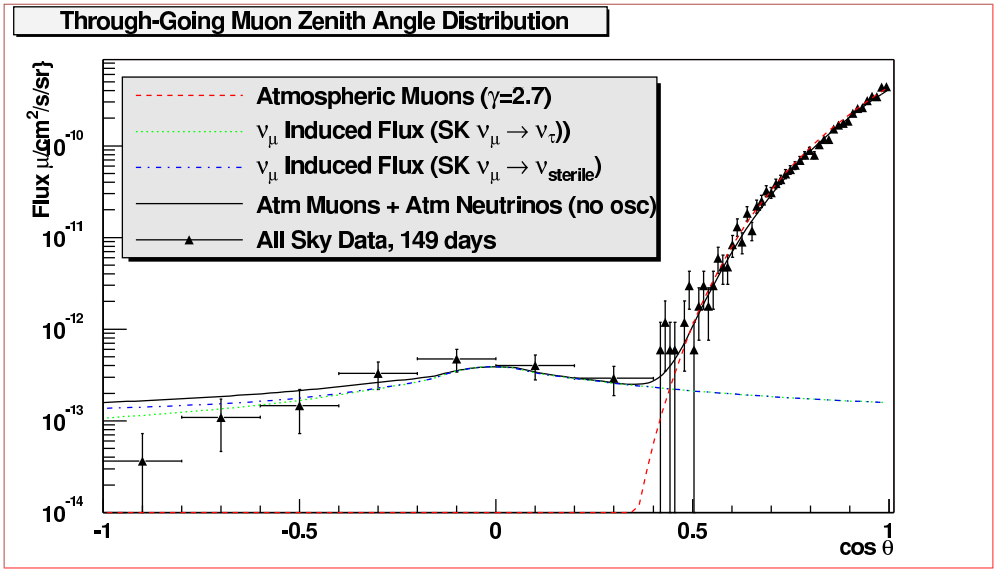


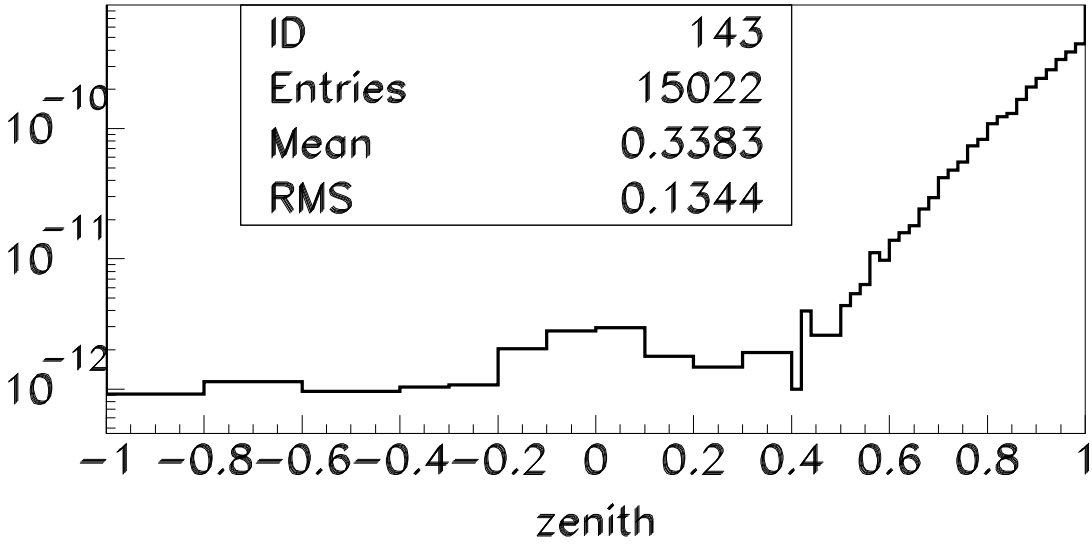


- Noticed that the DAMN mask and the FTM goodness-of-fit cuts are mostly overlapping. Good sign: FTM is bad at whatever is not a muon.
- MC N_{hit} peaks too high (by around 10%, cf p.5)

Preliminary outcome

Looking at the zenith angle distribution and attempt to normalize to an intensity. *Top:* 2001 analysis on D2O data. *Bottom:* current coarse out-of-the-box analysis on salt set I.





☞ Symmetric separation around the horizon is here! The fluxes don't compare yet. Bins very sensitive to cuts. More careful work needed at this point.

Perspectives

- The muon MC and the fitter are stable and operational!
- Original through-going muon analysis reproduces results in salt data

- More confidence needed in the cuts ⇨ understanding "sacrifice", "contamination", goodness-of-fit
- Re-examine event selection
- Enhance fitter's performance? Could NCDs help?
- Neutrino-induced muons in MC, MUSIC, oscillation scenarios

- Generate "standard" MC muons sample for general use?
- Timescale: first clean pass by collaboration meeting
- Paper for summer? D2O and/or salt combined?